Acoustic Propagation through Sound Speed Heterogeneity

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LONG-TERM GOALS

The goal of this work is to quantitatively understand the effects on low-frequency, long-range ocean acoustic propagation by small-scale variability in the sound speed. These variations are due to internal waves and to "spice", temperature and salinity variations that don't affect the water density.

OBJECTIVES

The LOAPEX and PhilSea experiments combine low-frequency acoustic propagation with some measurement of the environment. The objective is to be able to model the effects on the acoustics of the small scales in the measured environment. An environmental model consistent with the data must be constructed, and that model used to predict the acoustics. The sound speed variability in the environment is due to internal waves that modify the density and to temperature-salinity variability that doesn't affect the density, which is known as "spice".

APPROACH

The environmental data includes CTD profiles in both experiments and CTD chain tows in PhilSea. The CTD profiles are analyzed under the assumption that the small-scale vertical fluctuations in the data consist of internal waves and spice. A postiori checks are made of this assumption. No attempt is made to separate the large-scale (low mode) internal waves and spice from the background stratification. This work is in collaboration with Andrew White, a graduate student in our lab.

The towed CTD measurements from the 2009 component of PhilSea have data quality issues. While engineering work goes on for improving the instrumentation so that the data will be better in the 2010 component of PhilSea and future uses of the towed chain, a data improvement algorithm developed in the previous use (the Shallow Water 2006 experiment) of the towed chain is being applied to the PhilSea 2009 data. Eventually, the data will be interpolated onto a Cartesian grid for use in model building. The internal wave part of the towed chain data is partially redundant with a Garrett-Munk model fit to the profile data, but the spice part cannot be deduced from the profiles. The towed chain data also determines the large-scale internal waves that a single profile cannot. This work is done in collaboration with Andy Ganse and other members of Jim Mercer's group.

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The acoustic predictions will be made with a Monte Carlo PE model. The internal wave environment is provided by a dynamically correct simulation that was developed a number of years ago. This simulation allows an arbitrary internal wave spectrum, and has a much longer range without periodicity than similar methods with sufficient resolution. It is expected that Andrew White will participate in this work.

WORK COMPLETED

The vertical structure of the small-scale internal waves and spice in LOAPEX and PhilSea 2009 has been extracted from the CTD profiles.

The forward problem part of the tracking algorithm used in PhilSea 2009 for the source has been corrected, which is required so that the mean acoustic field can be extracted from the data.

RESULTS

Large-scale sound speed fluctuations are responsible for most of the fluctuations in acoustic travel time, but the effects of small-scale fluctuations dominate most other statistics such as intensity fluctuations and the vertical coherence function. These small scales are also where the assumptions (similar to ray tracing) made by some existing theories are most questionable.

The small-scale internal waves and spice have been extracted from CTD profiles taken in both LOAPEX and PhilSea 2009, and compared. Representative sections of these small-scales are shown in the figure.

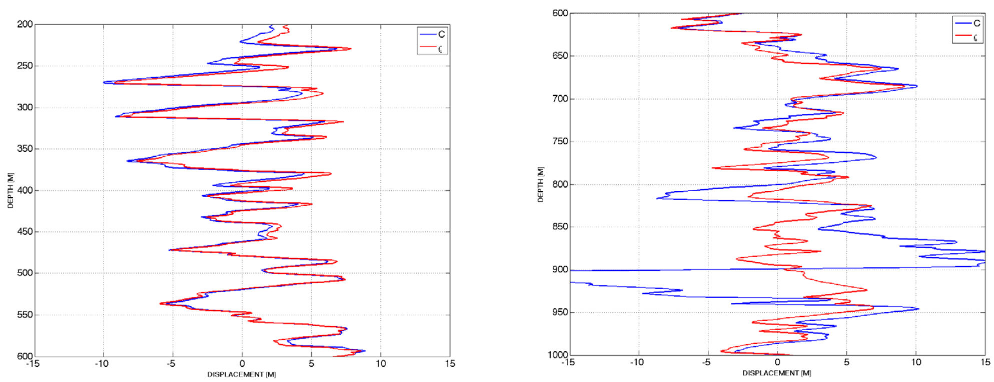

Figure: Representative 400 m sections of small-scale density displacement (red curves) and sound speed pseudodisplacement (blue curves). The displacement axes in both panels extend from -15 m to 15 m. The left panel is from the PhilSea 2009 experiment, and the right panel is from LOAPEX. See text for further discussion.

The figure shows displacement, defined in the usual way as the density anomaly divided by the nonadiabatic density gradient of the background stratification. It also shows the sound speed pseudodisplacement, defined in an analogous way using sound speed instead of density. The density displacement is due to internal waves (with a very small contribution from the "vortical mode"), while the sound speed pseudodisplacement is the sum of the density displacement and a contribution from

spice. In the PhilSea 2009 profiles, an example of which is shown in the left panel, both curves almost always are in very close agreement. This implies there was very little spice in these profiles. In LOAPEX, the sound speed pseudodisplacement fluctuations are often larger than the density displacement, as happens in a 150 m segment of the right panel. The two curves are in much closer agreement over the remaining 250 m. Thus, the spice fluctuations are large, and they are intermittent rather than being a Gaussian process -- a spectral model cannot match the observations. Moreover, these data say nothing about the horizontal structure of the spice fluctuations.

The magnitudes of the fluctuations are about the Garrett-Munk level, or a little larger in PhilSea, and about half Garrett-Munk for the LOAPEX internal waves, with the measured spice pseudodisplacement having about an equal variance.

RELATED PROJECTS

Work with Dajun Tang and others on Shallow Water 2006 data concerns the effects of internal waves and spice on mid-frequency propagation in shallow water. Not only is the topic closely related, but towed CTD chain measurements were also used to characterize the environment.

Work with Eric Thorsos and others concerns the variability in shallow water ocean acoustical propagation due to surface wave effects. As a part of this work, we compare PE calculation with a modal approach that we developed.